BRITE II Characterization and Application to a New Advanced Flight Motion Simulator

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ABSTRACT

Hardware-in-the-loop testing has, for many years, been an integral part of the modeling and simulation efforts at the U.S. Army Aviation and Missile Command's (AMCOM) Aviation and Missile Research, Engineering, and Development Center (AMRDEC). AMCOM's history includes the development, characterization, and implementation of several unique technologies for the creation of synthetic environments in the visible and infrared regions and AMCOM has continued significant efforts in these areas. Recently, AMCOM has been testing and characterizing a new state-of-the-art resistor array projector and advanced flight motion simulator (FMS). This paper describes recent test and integration activities of the Honeywell BRITE II emitter array and its integration into an infrared scene projector (IRSP) compatible with a new Carco Flight Motion Simulator (FMS).

Keywords: Infrared, Scene Projection, Emitter, Hardware-in-the-loop, BRITE, FMS

1. INTRODUCTION

1.1 AMCOM AMRDEC HWIL Facilities

The Aviation and Missile Research, Engineering, and Development Center (AMRDEC) of the U.S. Army Aviation and Missile Command (AMCOM) on Redstone Arsenal, Huntsville, Alabama, has an extensive history of applying all types of modeling and simulation (M&S) to weapon system development and has been a particularly strong advocate of hardware-in-the-loop (HWIL) simulation and test for many years. The AMCOM AMRDEC has been providing a full range of simulation support to Army Program Executive Officers (PEOs), Project Managers (PMs), other Armed Services agencies, and certain U.S. allies over the past 40 years. In addition, AMCOM AMRDEC has M&S support relationships with the U.S. Army Space and Missile Defense Command (SMDC), and the Redstone Technical Test Center (RTTC).

Within the AMRDEC, the Advanced Simulation Center's (ASC) role is to provide a dedicated, government-owned, high fidelity, verified and validated simulation and test tool to assist the project office and prime contractor during missile system development, test, production, and fielding by providing value-added HWIL capabilities. The ASC consists of fourteen (14) HWIL facilities and focuses on the engineering-level simulations that pertain to the missile elements. The ASC is divided into three main areas: Imaging Infrared System Simulation (I^2RSS), Radio Frequency System Simulation (RFSS), and Multi-Spectral System Simulation (MSSS). The I^2RSS supports imaging and non-imaging infrared missile programs in both the mid and long wave infrared wavebands and visible waveband. The RFSS supports the X, K, Ka, and W band radio frequency missile. The MSSS supports the common aperture and/or simultaneous imaging infrared, visible, semi-active laser (SAL) and/or millimeter wave (Ka and W band) missile programs.

1.2 Application of IRSP Technologies in HWIL testing
The AMRDEC ASC HWIL facilities have continued their long history of development, characterization, and/or operation of state-of-the-art simulation technologies. These technologies include scene generation hardware and software, scene projection hardware, flight simulators, digital simulation software, flight motion simulators, and facility control systems. One key element within the HWIL facilities is the infrared scene projector (IRSP) system. These systems provide dynamic, two-dimensional in-band infrared imagery to the unit under test (UUT). The AMRDEC ASC has investigated many promising technologies as the basis for the IRSP including laser diodes, emitter arrays, thermo-scenes, and MEMS devices. Projector systems employed at the AMRDEC based on these technologies are outlined in Figure 1 below and include: the Zoom Projector based on thermo-scenes and zoom optics; the Laser Diode Array Projector (LDAP) based on cryogenically cooled laser diodes; the Wideband Infrared Scene Projector (WISP) and the Multispectral Infrared Animation Generation Engine (MIRAGE) based on emitter arrays; and the Micromirror Array Projector System (MAPS) based on the digital micromirror devices. The Honeywell emitter array devices represent a mature technology that has become an integral part of the infrared simulation activities at the AMRDEC ASC. In 1998, the AMRDEC ASC acquired its first Honeywell emitter array device known as the BRITE I. During the following years, the AMRDEC has continued to acquire the latest in Honeywell emitter array devices culminating in the recent acquisition of the BRITE II.

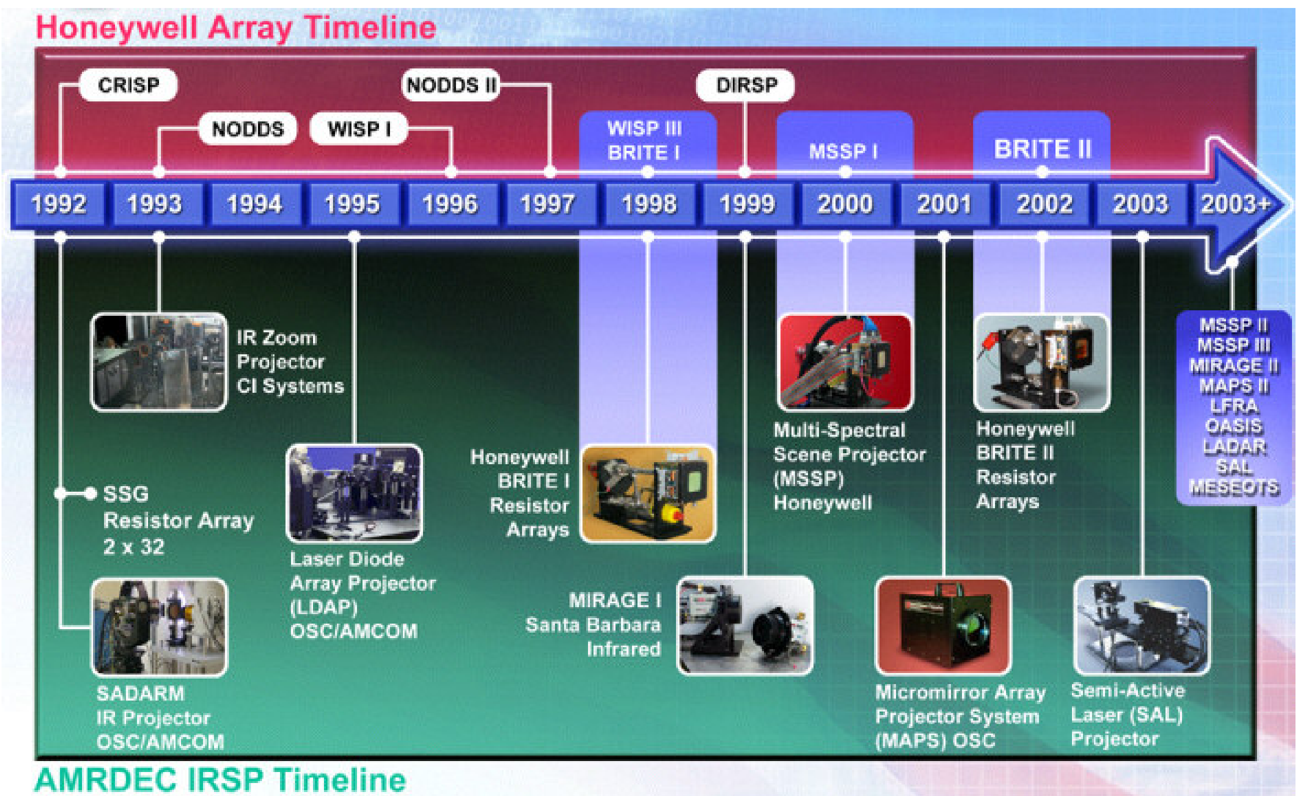
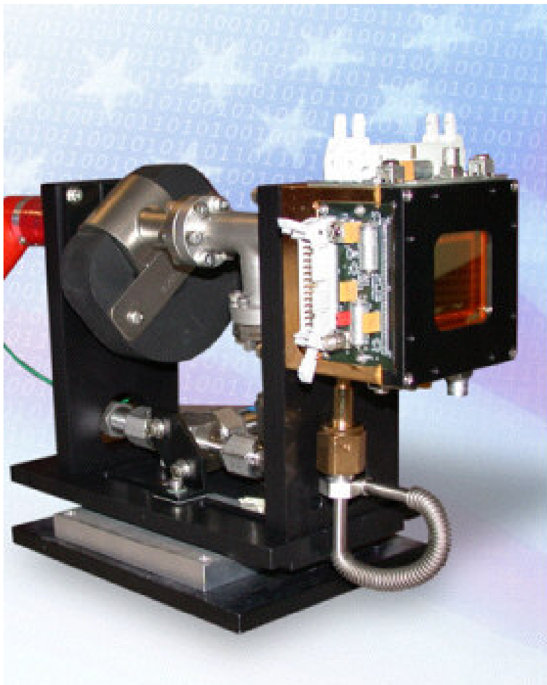


Figure 1 – Timelines for Honeywell Array Development and AMCOM IRSP Efforts

1.3 ***Honeywell Emitter Arrays***
The emitter array technology developed and built by Honeywell Technology Center (HTC) continues to provide state-of-the-art capabilities for the testing of imaging infrared seekers and sensors. The newest version, designated BRITE II, represents the final emitter array design to be offered by the HTC. The BRITE II was manufactured in two array subtypes by Honeywell and includes new features unavailable in previous emitter array models. The two array subtypes within the BRITE II product line are designated: standard range (SR) and extended range (ER). These ranges refer to the voltage range over which the emitter array may be driven. The SR array follows previous Honeywell emitter array designs providing an ~2 volt range of operation. The ER array offers a new capability with a larger ~3.5 volt range of

operation. This ‘extended’ range provides for a significantly improved capability when the array is operated under cryogenic conditions. Figure 2 below provides a picture of the BRITE II ER array acquired by the ASC and summarizes the requirements placed on each model type. The AMCOM AMRDEC ASC has continued its significant investment in this technology through the acquisition of a Grade A BRITE II Extended Range (ER) emitter array. This array is the only known BRITE II array in use within the United States test community.



Requirements	BRITE I	BRITE II SR*	BRITE II ER
Format	512x512	512x512	512x512
Operability	>99.9%	>99.9%	>99.9%
10-90% Risetime	<8ms	<6ms	<6ms
Max MWIR Temp	≥700K	≥650K	≥650K
Update Scheme	Raster	Raster Snapshot	Raster Snapshot
Optimized Substrate Temp.	273 K	273 K	77 K
Extended Voltage Range Operation	NA	NA	180uA @ 4.3V (300K)

* Australia DSTO has accepted the only known commercially delivered BRITE II SR array.

Figure 2 – BRITE II SR and ER Array Requirements

2. BRITE II ER ARRAY TESTING

2.1 Test Definition and Setup

The AMCOM AMRDEC ASC has recently completed a set of characterization tests on a Honeywell BRITE II ER array. These tests were intended to determine the level of performance as defined by several key parameters and to insure the array met specification. The following tests were performed and their results are discussed in this paper: risetime, maximum apparent mid-wave infrared (MWIR) temperature, cryogenic operation current draw, and extended voltage range operation. Test imagery under various operating conditions was also collected and is presented within this paper.

Testing of the BRITE II ER emitter array involved collecting data in multiple modes (raster and snapshot) and under various environmental conditions (room temperature and cryogenic substrate temperature). Two hardware assets developed at the ASC were vital to performing these tests: the emitter array miniature drive electronics and the cryogenic test chamber. The Honeywell BRITE II ER array required a unique set of drive electronics unavailable from any commercial or governmental group. The ASC modified electronics previously developed at the ASC to support this new array. The ASC emitter array electronics support both raster and snapshot updating mode as well as operation in the extended voltage range mode.

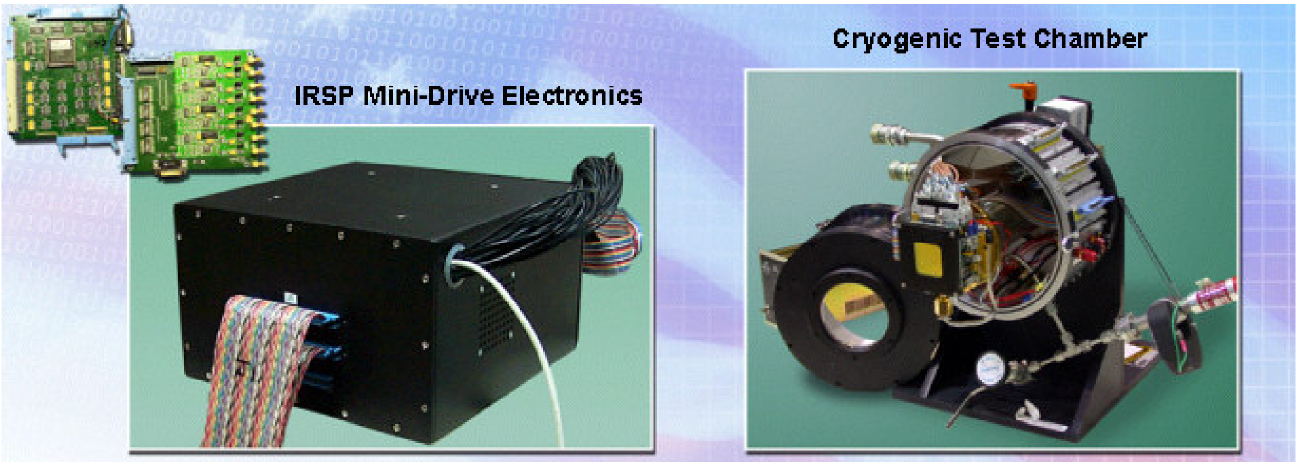


Figure 3 – ASC Emitter Array Drive Electronics and Cryogenic Test Chamber

Testing of the extended voltage range mode required operation of the array at cryogenic substrate temperatures. To achieve this, the ASC designed, built and tested a small cryogenic chamber capable of holding the entire BRITE II ER array and heatsink package. The cryogenic test chamber provides for a controlled environmental operating temperature over a range from 40K to 300K. Figure 3 above shows the ASC emitter array drive electronics and the cryogenic test chamber.

2.2 BRITE II ER Array Risetime Measurements

The response time of the emitter array is a function of the method used to read in the scene information and the time required by each individual emitter to change to the assigned thermal state. This 'time to change' the thermal state is referred to as 'risetime' when the new state is higher than the previous, and 'falltime' when the new state is lower than the previous. Precedent within the test community has lead to an informal definition for the 'risetime' measurement of the time required to change the output energy level from 10% of the commanded change to 90% of the commanded change. However, many HWIL applications demand that the desired state be reached to a higher accuracy then 90%. Knowledge of the *full* risetime is critical to understanding the dynamics of the HWIL test process and insuring no temporal anomalies occur. Measurements of the emitter array's risetime were made using both the raster updating mode of operation and the snapshot updating mode of operation. Figure 4 below shows the risetime measured using the raster updating mode. Figure 5 below shows the risetime measured using the snapshot updating mode.

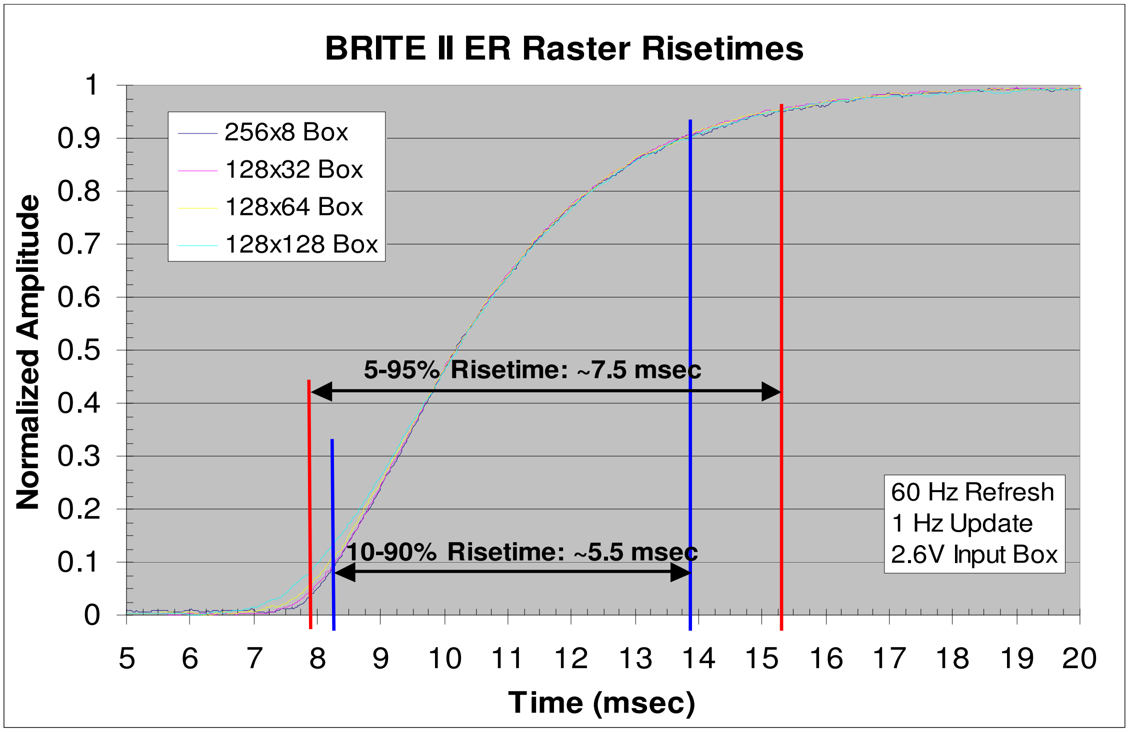


Figure 4 – BRITE II ER Emitter Array Risetime Measurement (Raster Mode)

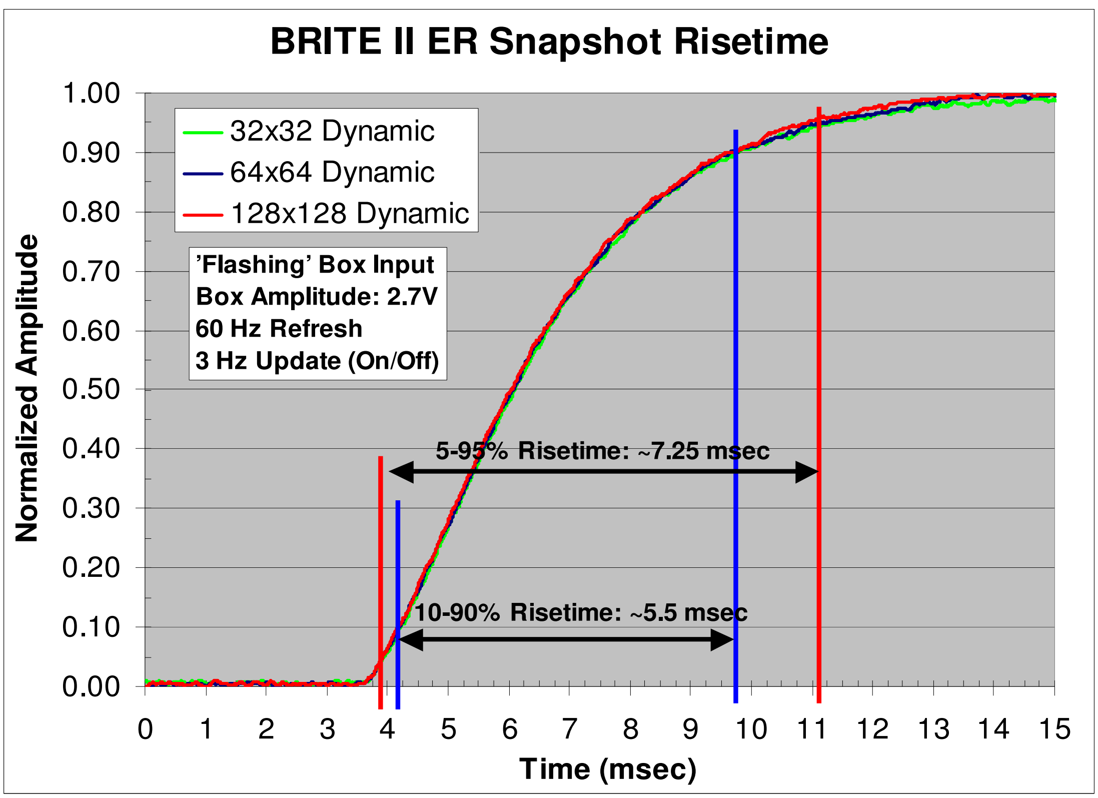


Figure 5 – BRITE II ER Emitter Array Risetime Measurement (Snapshot Mode)

2.3 BRITE II ER Array Maximum Apparent MWIR Temperature Measurements

The Honeywell emitter arrays consist of small thermally isolated microstructures that may be rapidly heated or cooled based on the amount of current driven through the microstructure. The BRITE II ER array uses a type of emitter known as Gossamer GE. This particular emitter structure is one of many types developed and tested by Honeywell, and provides a unique balance between response time and output (brightness). This 'brightness' can be quantitatively described in terms of the corresponding blackbody temperature that generates the same in-band output energy as the emitter array. This measurement, when performed within the mid-wave (3-5um) infrared band, is referred to as the maximum apparent MWIR temperature. Figure 6 below shows the apparent MWIR temperature versus emitter drive current. The comparison to Honeywell predictions shows good agreement and the 650K requirement for the array is met at an input level below what is considered the maximum safe drive current. The small discrepancy may be attributed to the difference between a single emitter response (theoretically modeled by Honeywell) and a larger area response (used in the measurement).

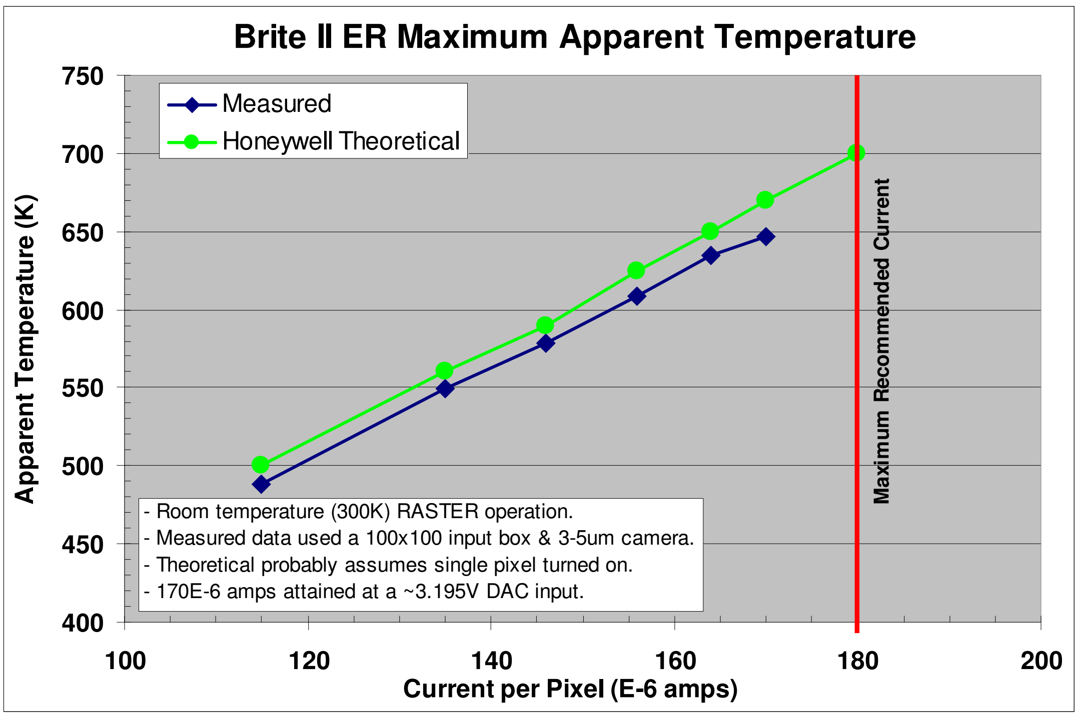


Figure 6 – BRITE II ER Array Maximum Apparent Temperature

2.4 BRITE II ER Array Extended Voltage Range Operation Measurements

As discussed in section 1.3, the BRITE II ER array provides a larger working voltage range than that of the BRITE II SR or other Honeywell emitter arrays. This 'expanded voltage range' capability was designed to directly address the loss of amplitude resolution that occurs when an array designed for 'room temperature' operation is operated at cryogenic temperatures. Due to an increase in the efficiency of the unit cell at cryogenic temperatures, the full output of the emitter is attained at a much smaller input voltage level as compared to room temperature operation. With a fixed A/D conversion range, this 'shrinking' of the useable voltage range resulted in significantly lower amplitude resolution. The BRITE II ER design expands the operational voltage range at room temperature. The voltage scale range during cryogenic operation of the BRITE II ER therefore 'shrinks' to a range comparable to that found with other Honeywell arrays operated at room temperature. This provides amplitude resolutions under cryogenics operating conditions on the order of 14 bits. Figure 7 below shows measurements taken while operating the BRITE II ER array in the extended voltage range mode. Honeywell predictions for the acceptable input voltage range, as limited by the maximum safe input current level, are shown for operating substrate temperatures of 300K and 77K. The 'shrinking' that occurs in the available input voltage range is immediately evident and measurements taken at the ASC are in good agreement with these predictions.

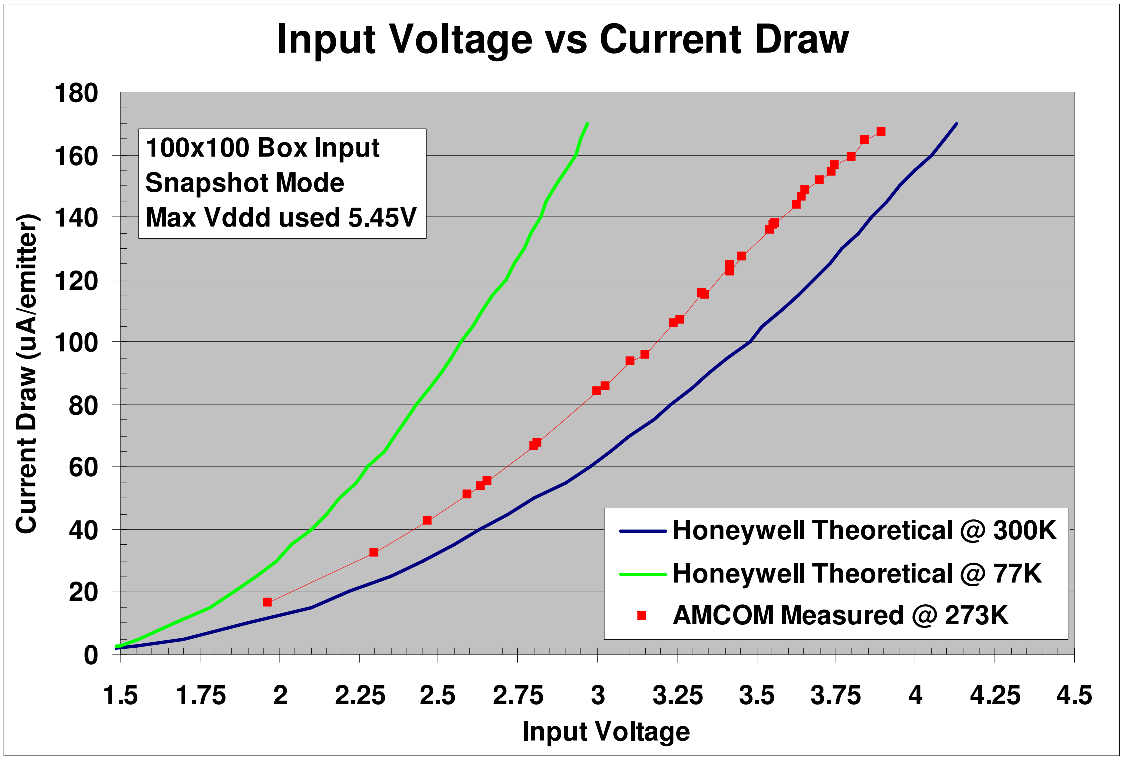


Figure 7 – BRITE II ER Extended Voltage Range Performance

2.5 BRITE II ER Array Room Temperature Example MWIR Imagery

Evaluation of the various technologies upon which the IRSP systems are based is often done qualitatively using visual inspection of the imagery generated by these two dimensional devices. Imagery provides a quick top-level evaluation of the uniformity of the IRSP. Figure 8 below shows two example images collected with a high-resolution MWIR camera viewing the BRITE II ER array. These images were generated with the BRITE II ER array substrate operating near room temperature and in a 'standard voltage range' mode. These images clearly demonstrate that the array exhibits exceptional uniformity and overall image quality.

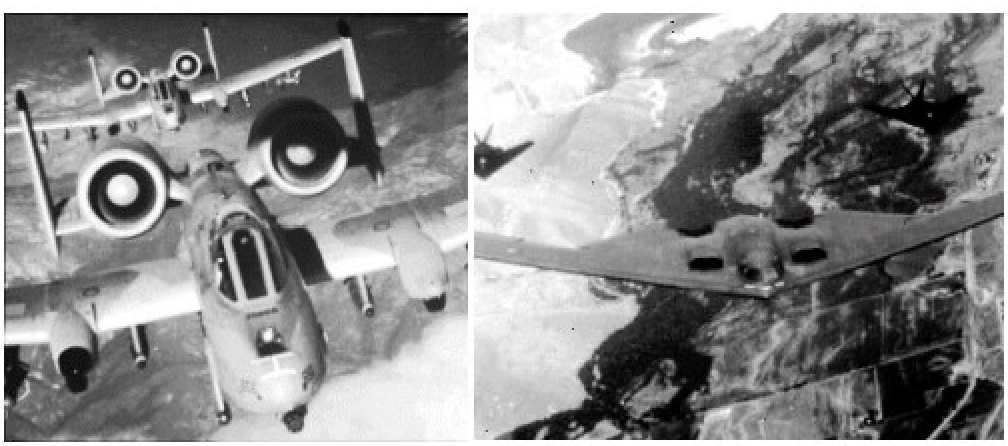


Figure 8 – BRITE II ER 290K Standard Voltage Range Mode MWIR Imagery

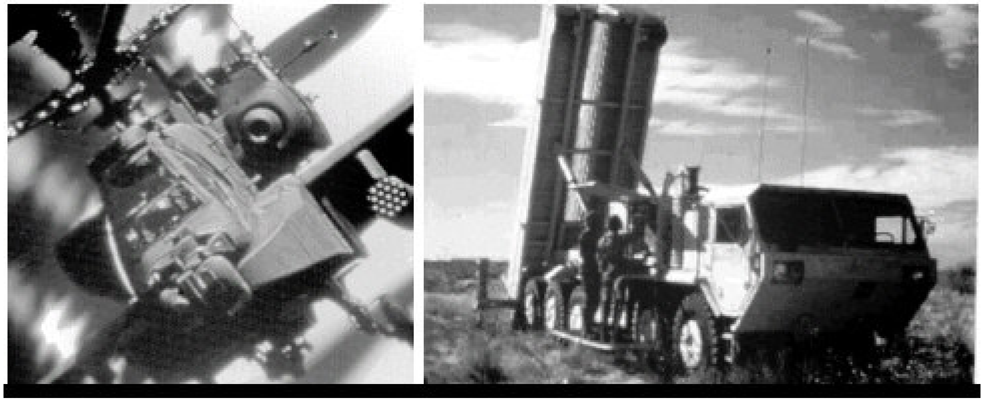


Figure 9 – BRITE II ER 290K Extended Voltage Range Mode MWIR Imagery

2.6 BRITE II ER Array Cryogenic Test Measurements

The Honeywell BRITE II ER array is uniquely designed for operation at room temperature and cryogenic substrate operation. Key to this capability is the operation of the array in extended voltage range mode. As discussed in section 2.4, this extended voltage range provides for an acceptable input voltage range while operating at cryogenic temperatures. The AMRDEC ASC performed measurements to map the output of the BRITE II ER array across a broad range of substrate temperatures. Figure 10 below shows the current drawn by each emitter array driven during testing. Two input voltages were used to drive a 100x100 central section of the emitter array. The average current draw per pixel within this box is plotted against Honeywell predictions at two substrate temperatures: 77K and 300K. Good agreement between the predictions and measurements can be seen and the extended voltage range mode appears to be performing as expected.

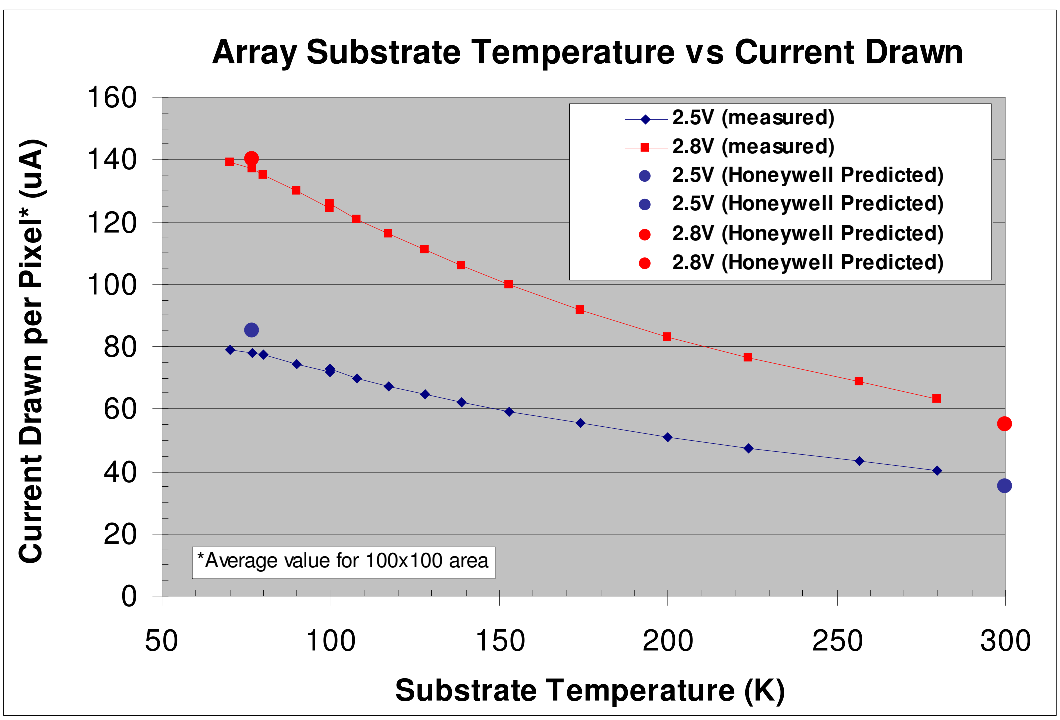


Figure 10 – BRITE II ER Array Cryogenic Operation Performance

2.7 BRITE II ER Array Cryogenic Operation MWIR Imagery
Figure 11 presents imagery from a high resolution MWIR camera viewing the BRITE II ER operating at a substrate temperature of 100K. The BRITE II ER array was configured in extended voltage range mode and snapshot updating mode for this data collection. As with the room temperature MWIR imagery, outstanding uniformity and overall image quality is evident.

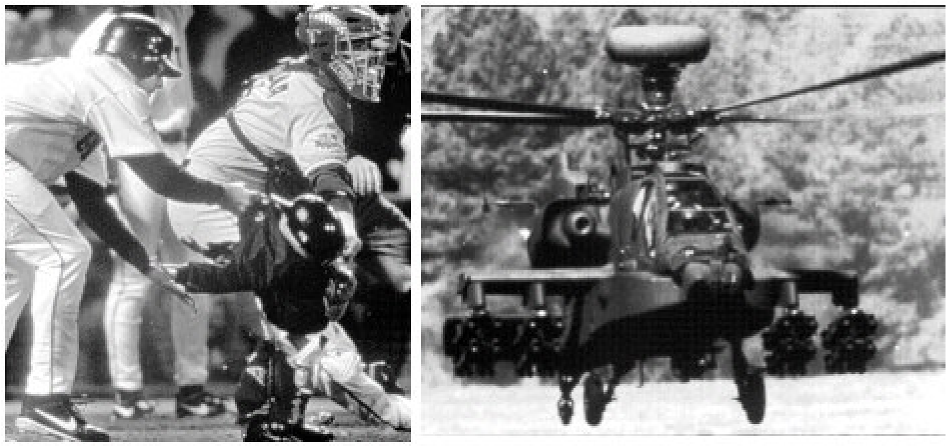


Figure 11 – BRITE II ER Array Cryogenic (100K) Operation MWIR Imagery

3. INTEGRATION OF THE BRITE II ER ARRAY ON AN FMS IRSP
The characterization and testing of the BRITE II ER array within the AMRDEC ASC facilities was performed in preparation for integration of this technology into the latest state-of-the-art infrared projector system (IRSP) within a new Flight Motion Simulator (FMS). The following two sections briefly discuss the FMS, the design restrictions placed on the IRSP by the FMS, and the preliminary design of the FMS-compatible IRSP.

3.1 FMS Table
The AMCOM ASC has recently acquired a new all-electric 5-axis Flight Motion Simulator (FMS) table. This table, unlike other CARCO 5-axis tables within the ASC, uses a 'bow-tie' design for the fourth and fifth axis. This table design places the fifth arm underneath the fourth and restricts any test equipment payload to a well-defined volume. Figure 12 below shows a picture of the 5-axis table as configured within the AMRDEC ASC HWIL laboratory facility. The IRSP framework is attached to the 5^{th} axis and provides an illustration of the limited volume available to the IRSP test equipment. Specifically, this volume is restricted to an approximate size of 27"x20"x17".

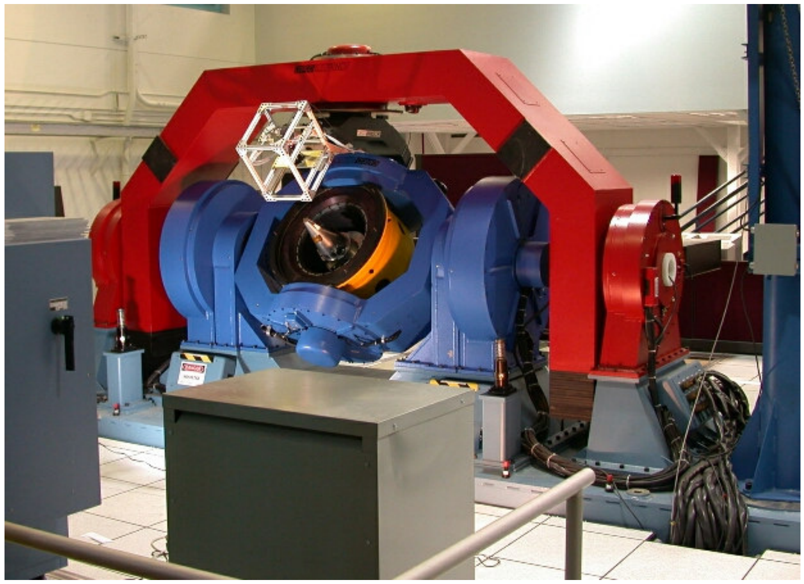


Figure 12 – FMS Table in the AMRDEC ASC

3.2 FMS IRSP

The IRSP design for integration into the FMS table must meet stringent volume constraints, provide the necessary performance capabilities, and minimize the on-table weight. Performance specifications for the IRSP were intended to incorporate the new features of the BRITE II ER array as well as other technologies implemented in previous AMRDEC ASC HWIL IRSP systems. Table 1 below lists the proposed capabilities of this IRSP system.

Table 1: AMRDEC ASC FMS IRSP Projector Specifications

2-D Sources	Honeywell BRITE II (chilled) Honeywell BRITE II (cryo) MIRAGE (chilled)	**Scene LOS Control**	High speed 2-axis steering mirror
Zoom Range	2.1X	**Volume**	27"x20"x17"
Waveband	MWIR	**Weight**	75-150lbs
Pupil Relief	40 inches		
Supplemental Sources	Single laser diode point source		
System Environment	Purged and cooled		

Figure 13 below provides an illustration of the IRSP configured onto the FMS 5th axis. Additionally, 3-D drawings of the IRSP and its mechanical 'skeleton' are also shown. The projector optical and mechanical subsystems are currently in fabrication and an August IOC is anticipated.

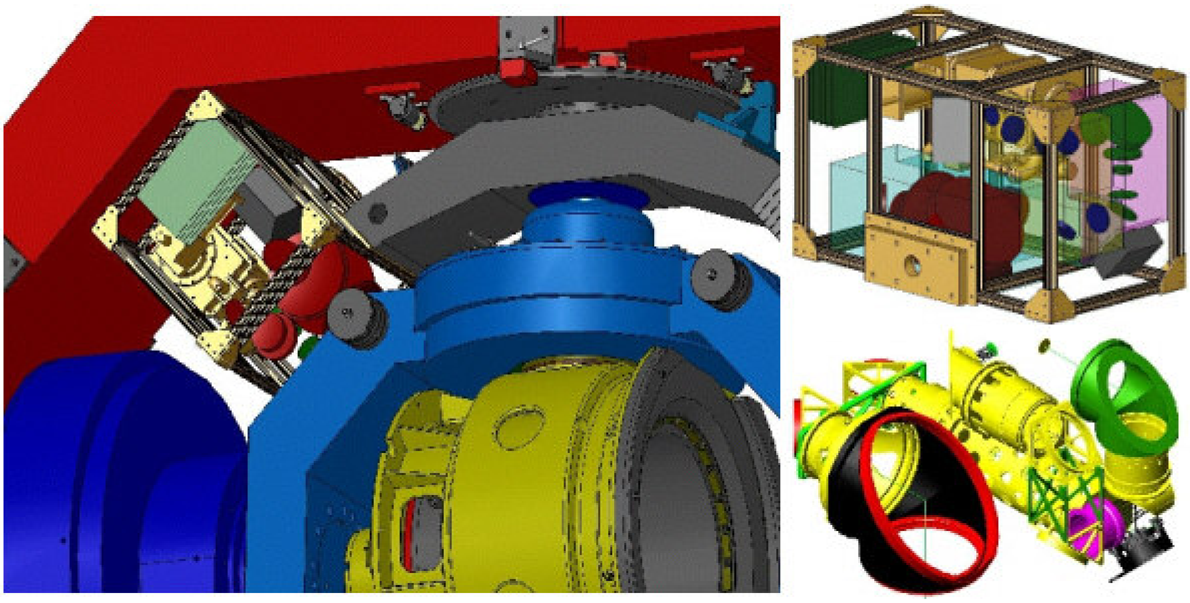


Figure 13 – AMRDEC ASC FMS IRSP Design Illustrations

4.0 SUMMARY

The AMCOM AMRDEC has performed characterization and performance testing on the latest Honeywell emitter array model: the BRITE II. Ongoing efforts will integrate this device into a state-of-the-art FMS-compatible infrared scene projector (IRSP) system for use within the AMRDEC ASC HWIL facilities.